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Feasibility Impact Analysis Report
Surface Vessel Bilgewater/Oil Water Separator

Section 8.0 – LSD 41 Class: Vessels with Compression Ignition Engines in the Whidbey Island Class

2003

SECTION 8.0 – LSD 41 CLASS

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8.0 LSD 41 CLASS

The USS WHIDBEY ISLAND Class (LSD 41) was selected to represent the group of large vessels that rely on compression ignition engines for main propulsion. There are eight vessels within the LSD 41 vessel class. LSD 41 Class vessels operate 190 days annually beyond 12 nautical miles (nm) of shore (Navy and EPA, 2003). The total volume of bilgewater generated within 12 nm is calculated by adding the volume of bilgewater generated in port to the volume generated while operating within 12 nm (e.g., transiting out to 12 nm). LSD 41 Class vessels spend approximately 175 days within 12 nm of shore: transits account for 5 cumulative days annually, and the remaining 170 days are spent pierside (Navy and EPA, 2003). The in-port bilgewater generation rate is 2,500 gallons per day (gpd), and the underway (both transiting and beyond 12 nm) rate is 10,000 gpd (Navy and EPA, 2003). Each vessel in this class generates approximately 475,000 gallons of bilgewater within 12 nm and 1,900,000 gallons of bilgewater beyond 12 nm annually.

Bilgewater generated within 12 nm of shore:

$$\frac{170\text{ days (pierside)}}{\text{yr}} \bullet \frac{2{,}500\text{ gal}}{\text{day}} + \frac{5\text{ days (underway)}}{\text{yr}} \bullet \frac{10{,}000\text{ gal}}{\text{day}} = 475{,}000\text{ gal/yr}$$

Bilgewater generated beyond 12 nm:

$$\frac{190\text{ days (underway)}}{\text{yr}} \bullet \frac{10{,}000\text{ gal}}{\text{day}} = 1{,}900{,}000\text{ gal/yr}$$

LSD 41 Class vessels are equipped with two gravity coalescing oil water separators (OWSs) (Navy model OPB-10NP) that are rated at 10 gallons per minute (gpm) each, for a total processing capacity of 20 gpm. Consequently, this option is the current marine pollution control device (MPCD). The total processing capacity of 20 gpm will be used for all of the following analyses for this vessel class. These vessels operate one 50-gpm pump to transfer oily waste and waste oil to shore collection facilities.

Where appropriate, the current MPCD was used to determine the operational capacities and other parameters used to evaluate each of the MPCDs in the feasibility analysis. The following MPCDs are evaluated for the LSD 41 Class vessel: gravity coalescence, centrifuge, collection, holding, and transfer (CHT), evaporation, hydrocyclones, *in situ* biological treatment, oil absorbing socks, filter media, and membrane filtration.

8.1 GRAVITY COALESCENCE

The following sections discuss the feasibility and cost impacts of installing and operating a gravity coalescence unit on-board an LSD 41 Class vessel.

8.1.1 Practicability and Operational Impact Analysis

This section describes the analyses of specific feasibility criteria relative to the physical characteristics and operational requirements of gravity coalescence units.

8.1.1.1 Space and Weight

As described in Section 8.0, the analysis of gravity coalescence will include two 10-gpm gravity coalescer units (Navy model OPB-10NP) and one 50-gpm pump. The gravity coalescence OWSs on-board these vessels are intended for single-deck operation and are commonly installed in main or auxiliary machinery spaces, in the vicinity of the oily waste holding tank (OWHT). Table 8-1 provides the space and weight for the OPB-10NP.

Table 8-1. OPB-10NP Specifications (LSD 41 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	6 x 2.5 x 4.2	10 x 4.5 x 6.2	63	1250/2710
Total (To achieve required processing capacity)	2	20 gpm	-	-	126	2500/5420

Clearance is required above the OWS tank assembly to mount chain falls for removal of the tank cover.

8.1.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with gravity coalescence units. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use on-board vessels of the Armed Forces. Standard afloat control and management procedures are adequate for use and disposal of the material. While gravity coalescence units require electrical power, existing standard shipboard safety procedures for handling electrical equipment have been adequate to protect personnel safety.

8.1.1.3 Mission Capabilities

The use of the OPB-10NP units on LSD 41 Class vessels has not resulted in any impact on ship's signature, war-fighting capabilities, mobility, or on any mission critical systems or operations.

8.1.1.4 Personnel Impact

The OPB-10NP separators run in automatic mode, but require general supervision while the units are operating. Based on a combined rated capacity of 20 gpm (for both units) and the approximate 475,000 gallons of bilgewater generated annually within 12 nm, the number of hours each gravity coalescer is operated annually within 12 nm is 400 hours.

$$\frac{475{,}000\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{20\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} = 400\ \text{hr/yr}$$

Based on operational experience, the time required per year to supervise the operation of the OPB-10NP separators is 0.25 hours (15 minutes) for every two hours the unit operates. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. It is assumed that the time required to oversee both separator units will be the same as for a single unit. Based on the annual operating requirement of 400 hours, the annual labor requirement associated with the operation of both gravity coalescence units within 12 nm is 49 hours, as calculated below:

$$\frac{400\text{ hrs operation}}{\text{yr}} \bullet \frac{0.25\text{ hr labor}}{2\text{ hrs operation}} = 49\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires the oversight of three crewmembers per event. One crewmember is required to operate the waste oil transfer pump and associated valves/hull connections. A second crewmember is required to oversee the connection of transfer hoses for the offloading vessel. A third crewmember oversees the connection of transfer hoses for the receiving vessel or facility. The two crewmembers overseeing the transfer hose connections stand near the hose connections in case the connections separate. The two crewmembers overseeing the transfer generally ensure that appropriate precautions are taken to prevent oil spills. During waste oil transfer activities, two-way voice communication must be established between the three crewmembers overseeing the oil transfer (Navy, 2002). The labor hours associated with transferring the waste oil produced within 12 nm from shore by a gravity coalescence unit on the LSD 41 are calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (50 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}750\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 4.8\text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of both gravity coalescence units within 12 nm and transfer of waste oil generated within 12 nm on an LSD 41 class vessel is 54 hours.

The total labor requirement associated with gravity coalescence operation beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. The volume (i.e., 1,900,000 gal) of bilgewater generated beyond 12 nm and resultant volume (i.e. 19,000 gal) of waste oil that requires offloading to shore are based on the LSD 41 Class vessel underway bilgewater generation rate of 10,000 gpd. The underway generation rate is multiplied by the number of days (190 days) spent beyond 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}900{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{20\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 1{,}600\text{ hrs labor/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{1600\text{ hrs}}{\text{yr}} \bullet \frac{0.25\text{ hrs labor}}{2\text{ hrs}} = 198\text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{19{,}000\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{3\text{ hrs labor}}{\text{hr}} = 19\text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of both OPB-10NP separators on an LSD 41 Class vessel class beyond 12 nm is 217 hrs/yr.

Annually, each OPB-10NP requires approximately 4.1 personnel hours of time-based maintenance, 8.6 personnel hours of condition-based maintenance within 12 nm, and 34 personnel hours of condition-based maintenance beyond 12 nm. Table 8-2 and Table 8-3 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one OPB-10NP separator.

Table 8-2. OPB-10NP Time-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Lubricate Pump Packing	0.1	6 months	0.2
Inspect Air Vent Valve	1	6 months	2
Clean and Inspect Flow Totalizer	1	12 months	1
Inspect OWS Pump Assembly Drive Belt	0.2	12 months	0.2
Lubricate OWS Pump Motor Bearings	0.5	12 months	0.5
Test Operation of OWS Pump Relief Valve	0.3	18 months	0.2
Total Annualized Hours (per unit)	-	-	4.1
Total Annualized Hours (per vessel)	-	-	8.2

Table 8-3. OPB-10NP Condition-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 400 operation hours within 12 nm)	Annualized Maintenance Hours (based on 1600 operation hours beyond 12 nm)
Clean and Inspect Check Valves	0.5	1000	0.2	0.79
Clean and Inspect Separator Level Sensor Probes	0.8	1500	0.21	0.84
Clean and Inspect Coalescing Plates and Separator Tank	16	1000	6.3	25
Lubricate OWS Pump Bearings	7	1500	1.9	7.5
Total Annualized Hours (per unit)	-	-	8.6	34
Total Annualized Hours (total)	-	-	17.2	69

Table 8-4 provides the annual labor hours required to operate and maintain the current gravity coalescer.

Table 8-4. Gravity Coalescer Annual Labor Hours (LSD 41 Class)

	Gravity Coalescer (10NP) (hours/unit)
Operator Hours Within 12 nm	54
Operator Hours Beyond 12 nm	217
Condition-based Maintenance Within 12 nm	17.2
Condition-based Maintenance Beyond 12 nm	69
Time-based Maintenance	8.2
Total Time	365

8.1.1.5 Consumables, Repair Parts, and Tools

Gravity coalescence units installed on LSD 41 Class vessels do not require consumables. No special tools are required for the operation or maintenance of these units.

8.1.1.6 Interface Requirements

Table 8-5 summarizes specific system interface requirements associated with the OPB-10NP.

Table 8-5. OPB-10NP Interface Requirements (LSD 41 Class)

Shipboard System	OPB-10NP Interface Requirements
Electrical Power	440V/3PH/60Hz 1.5 kW (2 hp)
Potable Water	May be used for priming
Seawater	Minimal pressure required for priming
Drainage	Gravity drain to bilge or OWHT

8.1.1.7 Control System Requirements

The gravity coalescence units installed on-board the LSD 41 Class are designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. One level switch starts the units when the liquid level in the tank reaches a pre-set level. When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the units to shut down. Units have a flow sensor that will secure the system if the pump loses suction and a remote alarm/indicator panel that will allow shipboard personnel to monitor the operating status of the units while in the automatic mode of operation. The remote alarm/indicator contains visual indicators that allow operating personnel to monitor the overall status of the system and an audible alarm that warns of system malfunction.

In addition, OPB-10NP units are equipped with an oil content monitor (OCM) to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than a predetermined concentration, the OCM will redirect the effluent back to the OWHT to be reprocessed by the OWS.

8.1.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

8.1.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a gravity coalescence system on an LSD 41 Class vessel.

8.1.2.1 Initial Cost

There are no initial costs associated with gravity coalescence on an LSD 41 Class vessel because the equipment is in place as described above.

8.1.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 80 personnel hours per year for operation within 12 nm, maintenance, and offloading waste oil generated within 12 nm, as explained under Section 8.1.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{80 \text{ hrs labor}}{\text{yr}} = \$1{,}800/\text{yr (within 12 nm)}$$

Personnel Labor Beyond 12 nm

This MPCD requires 286 personnel hours per year for operation beyond 12 nm and offloading waste oil generated beyond 12 nm, as explained under Section 8.1.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{286 \text{ hrs labor}}{\text{yr}} = \$6{,}460/\text{yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the gravity coalescence system to a disposal facility is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal facility is assumed to dispose of the waste oil at no charge for Navy vessels.

Coast Guard vessels pay $0.91 per gallon to dispose of their waste oil (Volpe, 2000a). The recurring cost incurred by the Coast Guard to dispose of the waste oil generated within 12 nm is shown below.

$$\frac{4{,}750 \text{ gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$4{,}323/\text{yr}$$

The recurring cost incurred by the Coast Guard to dispose of waste oil generated beyond 12 nm is shown below.

$$\frac{19{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$17{,}290/\text{yr}$$

Table 8-6 summarizes the annual recurring costs for a gravity coalescence system used on an LSD 41 Class Vessel.

Table 8-6. Annual Recurring Costs for Gravity Coalescence (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	1.8
Beyond 12 nm	Navy	6.46
Within 12 nm	Coast Guard	6.1
Beyond 12 nm	Coast Guard	23.75

8.1.2.3 Total Ownership Cost (TOC)

Table 8-7 summarizes the TOC and annualized cost over a 15-year lifecycle for a gravity coalescer system on an LSD 41 Class vessel.

Table 8-7. TOC for Gravity Coalescence (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	0.00	0.00	0.00	0.00
Total Recurring	20	92	68	333
TOC (15-yr lifecycle)	20	92	68	333
Annualized	1.7	7.8	5.8	28.3

8.2 CENTRIFUGE

The following sections discuss the feasibility and cost impacts of installing and operating a centrifuge on-board an LSD 41 Class vessel.

8.2.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of centrifuges.

8.2.1.1 Space and Weight

One 15-gpm centrifuge unit (Westfalia model WSC-15) is proposed in this analysis. The unit is manufactured by a major supplier of centrifuges used in the marine industry and is representative in space, weight, and power requirements of centrifuges with a similar processing capacity. A single centrifuge unit was chosen because a 15-gpm capacity is sufficient and using two units with a combined 30-gpm capacity would not be justified considering the additional space and weight requirements to accommodate the additional unit. Table 8-8 provides the space and weight of the centrifuge, which comes as a complete 15-gpm module (includes one 15-gpm centrifuge and heater) unit.

Table 8-8. WSC-15 Specifications (LSD 41 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	15 gpm	4 x 5.25 x 6.5	5 x 6.5 x 7.3	137	2650/2700
Total (To achieve required processing capacity)	1	15 gpm	4 x 5.25 x 6.5	5 x 6.5 x 7.3	137	2650/2700

The centrifuge is designed for single deck operation and could be installed in the current OWS room. The existing OWS could be removed and replaced with the centrifuge unit.

8.2.1.2 Personnel/Equipment Safety

Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While centrifuges require electrical power, observing standard shipboard safety procedures for handling electrical equipment should be adequate. Integral heaters provided as part of the centrifuge module preheat the bilgewater to 90 - 95^{o}C. However, the heater and associated piping are insulated and should not pose a burn hazard to personnel.

8.2.1.3 Mission Capabilities

The installation and operation of centrifuges on LSD 41 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

8.2.1.4 Personnel Impact

The WSC-15 centrifuge runs in automatic mode, but requires general supervision while the unit is operating. Based on a rated capacity of 15 gpm and the approximate 475,000 gallons of bilgewater generated annually within 12 nm, the number of hours the centrifuge is operated annually within 12 nm is 530 hours.

$$\frac{475{,}000\,\text{gal}}{\text{yr}} \bullet \frac{\text{min}}{15\,\text{gal}} \bullet \frac{\text{hr}}{60\,\text{min}} = 530\text{ hrs/yr}$$

The labor requirement for general oversight of the centrifuge system was calculated as 0.25 hours for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, the annual labor requirement associated with the operation of a centrifuge unit within 12 nm is 66 hours.

$$\frac{530\,\text{hrs operation}}{\text{yr}} \bullet \frac{0.25\,\text{hr labor}}{2\,\text{hrs operation}} = 66\text{ hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 8.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm of shore is calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (50 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}750\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{50\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} \bullet \frac{3\ \text{hrs labor}}{\text{hr}} = 4.8\ \text{hrs labor/yr}$$

The combined annual labor associated with the operational oversight of a centrifuge unit within 12 nm and the transfer of waste oil generated within 12 nm on an LSD 41 class vessel is 71 hours.

The total labor requirement associated with vessel operations beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}900{,}000\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{15\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} = 2{,}100\ \text{hrs/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{2{,}100\ \text{hrs}}{\text{yr}} \bullet \frac{0.25\ \text{hrs labor}}{2\ \text{hrs}} = 260\ \text{hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{19{,}000\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{50\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} \bullet \frac{3\ \text{hrs labor}}{\text{hr}} = 19\ \text{hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of a WSC-15 centrifuge on an LSD 41 Class vessel class beyond 12 nm is 280 hrs/yr.

Annually, the WSC-15 centrifuge requires approximately 20.75 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 8-9 and Table 8-10 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for the WSC-15 centrifuge.

Table 8-9. WSC-15 Time-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Change gear case oil.	1	6 months	2
Remove, clean, and grease bowl lock ring, and re-install it.	1	6 months	2

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Grease motor bearings.	0.25	As needed*	0.25
Inspect and clean bowl: Remove bowl top. Clean sludge space and disks as required. If the bowl is removed during this procedure, ensure that the spindle cone and bowl nave are clean, dry, and free of grease.	2	3 months	8
Check starting time. Check thickness of clutch shoe linings. Replace as necessary.	0.25	6 months	0.5
Check thickness of brake lining. Replace as necessary.	0.5	12 months	0.5
Check foundation bolts for proper tensioning. Check all readily accessible equipment bolts and fasteners for proper tension.	0.5	12 months	0.5
Check shock mounts for cracks, peeling of rubber, or any distortions. Replace as necessary.	0.25	12 months	0.25
Check to ensure that a clearance of 3 mm between the decelerator unit and ship's foundation is correct.	0.25	12 months	0.25
Replace ball bearings on spindle	1	12 months	1
Replace ball bearings on worm wheel shaft	1	6 months	2
Check pump strainer. Clean as required.	0.25	6 months	0.5
Check water strainer(s). Clean as required.	0.25	6 months	0.5
Check to make sure operating water feeding device is not plugged.	0.25	6 months	0.5
Check and tighten system hardware including all foundations	1	12 months	1
Check motor winding resistance.	0.5	12 months	0.5
Check operation of pressure switch. Repair or replace as required.	0.25	6 months	0.5
Total Annualized Hours (per unit)	-	-	20.75
Total Annualized Hours (total)	-	-	20.75

** For calculations it was assumed that the condition-based maintenance was performed annually.*

Table 8-10. WSC-15 Condition-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 75 operation hours within 12 nm)	Annualized Maintenance Hours (based on 270 operation hours beyond 12 nm)
None	0	0	0	0
Total Annualized Hours (per unit)	-	-	-	0
Total Annualized Hours (total)	-	-	-	0

Centrifuges are equipped with programmable logic controls and monitoring systems. The oil content monitor alarm can be monitored remotely or locally.

Operator certification is not required. Inexperienced equipment operators require four to six hours of training. Properly operating centrifuges pose no impact on habitability.

Table 8-11 provides the annual labor hours required to operate and maintain the WSC-15 Centrifuge.

Table 8-11. Centrifuge Annual Labor Hours (LSD 41 Class)

	MPCD Option: WSC-15 Centrifuge (hours/unit)
Operator Hours Within 12 nm	71
Operator Hours Beyond 12 nm	280
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	20.75
Total Time	374

8.2.1.5 Consumables, Repair Parts, and Tools

Centrifuges require consumables, repair parts, and special tools. In addition, a spare parts kit is available from the vendor. Consumables and repair parts include items such as filters, gaskets, "O" rings, and bearings. The special tools required are delivered with the machine and consist of spanner wrenches made specifically for dismantling the purifier bowl.

8.2.1.6 Interface Requirements

Table 8-12 lists the interfaces required to support one WSC-15 centrifuge module.

Table 8-12. WSC-15 Interface Requirements (LSD 41 Class)

Shipboard System	WSC per unit
Electrical Power	60-100kW (80-134 hp) 440VAC/3PH,
Compressed Air	0.0058 - 0.029cfm @ 50 psig
Potable Water	20 gpd, 45 psi
Seawater	Requires 25 psi seawater pressure
Drainage	Gravity drain to OWHT

LSD 41 Class vessels are able to accommodate these interface requirements with no significant impact on existing systems.

8.2.1.7 Control System Requirements

The manufacturer recommends that the operator manually turn on the equipment. However, once the centrifuge has reached its operating speed, the WSC-15 does not require constant oversight. It is fully automatic and equipped with an integrated thermostat to control the heater.

A centrifuge will be equipped with an OCM to measure the oil content of OWS effluent. If the OCM detects an oil concentration greater than a predetermined concentration, the OCM will redirect the effluent back to the OWHT to be reprocessed by the OWS.

8.2.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

8.2.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare costs associated with a centrifuge system on an LSD 41 Class vessel.

8.2.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $138,000 (Donohue, 2000). Based on an LSD 47 (an LSD 41 Class vessel) ship check, the Navy estimates that the installation will cost $146,300 per vessel (Navy, 2000). To install the unit, the existing gravity coalescence unit must first be removed from the OWS room to make space available for the centrifuge system. The installation would require approximately six weeks to complete. Technical manuals cost approximately $85,000 ($10, 630 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $33,810 ($4,226 per vessel) (Navy, 2000). The cost of training materials includes the cost of development and implementation of a new module in an existing Navy training course. The cost for training materials is approximately $9,330 ($1,166 per vessel) (Smith, 2001). The initial cost of a centrifuge system on an LSD 41 Class vessel is $301,000.

8.2.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 91 personnel hours per year for operation and time-based maintenance within 12 nm as explained under Section 8.2.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the annual recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{91 \text{ hrs labor}}{\text{yr}} \bullet = \$2{,}100/\text{yr (within 12 nm)}$$

Personnel Labor Beyond 12 nm

This MPCD requires 280 personnel hours per year for operation beyond 12 nm, as explained under Section 8.2.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{280 \text{ hrs labor}}{\text{yr}} = \$6{,}400/\text{yr (outside 12 nm)}$$

The labor required to transfer waste oil generated by the centrifuge system to a disposal facility is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal facility is assumed to dispose of the waste oil at no charge for Navy vessels.

Coast Guard vessels pay $0.91 per gallon to dispose of their waste oil (Volpe, 2000a). The recurring cost incurred by the Coast Guard to dispose of the waste oil generated within 12 nm is shown below.

$$\frac{4{,}750 \text{ gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$4{,}323/\text{yr}$$

The recurring cost incurred by the Coast Guard to dispose of waste oil generated beyond 12 nm is shown below.

$$\frac{19{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$17{,}290/\text{yr}$$

Table 8-13 summarizes the annual recurring costs for a centrifuge system used on an LSD 41 Class Vessel.

Table 8-13. Annual Recurring Costs for Centrifuge (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	2.1
Beyond 12 nm	Navy	6.4
Within 12 nm	Coast Guard	6.4
Beyond 12 nm	Coast Guard	23.75

8.2.2.3 Total Ownership Cost

Table 8-14 summarizes the TOC and annualized cost over a 15-year lifecycle for a centrifuge system on an LSD 41 Class vessel.

Table 8-14. TOC for Centrifuge (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	301	301	301	301
Total Recurring	23.4	94.7	71.3	335
TOC (15-yr lifecycle)	324	396	372	636
Annualized	27.5	33.6	31.6	54.0

8.3 COLLECTION, HOLDING, AND TRANSFER (CHT)

The following sections discuss the feasibility and cost impacts of not discharging bilgewater (treated or untreated) from LSD 41 Class vessels to the environment within 12 nm from shore. This no-discharge option is referred to as the practice of CHT of bilgewater within 12 nm. The bilgewater may be transferred to shore facilities (including tanks, barges, and trucks) in port, processed through an OWS beyond 12 nm, or discharged overboard in accordance with applicable regulations beyond 12 nm.

For small new design vessels, NSWCCD Code 20, Total Ship Systems Engineering Group, evaluated the feasibility and cost impacts of practicing CHT on surface vessel bilgewater.

8.3.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of CHT.

8.3.1.1 Space and Weight

All LSD 41 Class vessels are equipped with a series of OWHTs that have a combined design capacity of approximately 6,500 gallons. These holding tanks are designed with capacity 5-10 percent in excess of the ship's requirements, to minimize the risk of overfilling the tanks, which would result in spillage. These vessels are designed to collect and hold oily waste (i.e., bilgewater) for processing by the vessel's 10-gpm OWS units or for transfer to shore, as applicable. As such, LSD 41 Class vessels are capable of practicing CHT up to the existing holding capacity without experiencing any impacts to space and weight. The potential for exceeding the vessel's existing space and weight capacities, as a result of practicing CHT, will depend upon the length of time spent within 12 nm from shore, and whether the port visited has the capability to offload wastewater.

During a typical five year operating cycle, LSD 41 Class vessels may visit many ports for varying lengths of time. The longest stays (i.e., 30 days or more) in port tend to be at the vessel’s homeport or at other major Naval ports, where extensive shore services, including wastewater offloading, are available. During these visits, LSD 41 Class vessels rarely operate their OWS units, but instead transfer their bilgewater to shore facilities. However, to support their operational requirements, LSD 41 Class vessels may occasionally visit smaller non-Navy ports where offloading services are not available. In this situation, an LSD 41 Class vessel could be required to collect and hold all bilgewater generated until the ship is beyond 12 nm. The following paragraphs will evaluate two potential scenarios: (1) arriving at a port where offloading services are available, and (2) arriving at a port where offloading services are not available.

Ports with wastewater offloading services: All LSD 41 Class ships are homeported in Norfolk, VA or San Diego, CA. These are major Navy ports with complete shore services, including wastewater offloading. Once a vessel has tied up pierside at one of these ports, the transfer of bilgewater to shore can be performed as needed. LSD 41 Class vessels can also collect and hold bilgewater generated while transiting from 12 nm to port for transfer shoreside. Both of these homeports are on the coast and a vessel can transit between these ports and 12 nm from shore within two to three hours. While underway, LSD 41 Class vessels generate approximately 10,000 gallons per day of bilgewater, or 400 gallons per hour. Using a generation rate of 400 gallons per hour over three hours, the maximum volume of bilgewater generated would be approximately 1,200 gallons. Because the 1,200 gallons collected during transit is well within the holding capacity for LSD 41 Class vessels, practicing CHT while transiting to or from a port where offloading facilities are available will have no space or weight impacts.

Ports without wastewater offloading services: If the vessel is visiting a port where offloading bilgewater is not possible, the ship could be required to hold all bilgewater during the entire time spent within 12 nm. A typical visit to a small port may last two to five days. Assuming a five-day port visit, an LSD 41 Class vessel would generate approximately 12,500 gallons of bilgewater (based on in port generation rate). Using a generation rate of 400 gallons per hour and a total transit time of 6 hours (3 hours in each direction), the vessel would generate an additional 2,400 gallons of bilgewater while transiting to and from port. The total bilgewater generated within 12 nm from shore would be 14,900 gallons. This is over twice the current safe holding capacity of the existing OWHTs, and accommodating that volume would likely result in adverse space and weight impacts. Under this scenario, an LSD 41 Class vessel would be limited to practicing CHT for less than two days so as not to exceed its design holding capacity. After exceeding the design holding capacity, it would not be possible for an LSD 41 Class vessel to comply with a no-discharge requirement, without expanding the bilgewater holding capacity. Using the OWS to process bilgewater from the bilge area as it is generated would decrease the OWS effectiveness. The OWHT acts as a pretreatment that allows the oil content to settle out of the bilgewater thereby allowing the OWS to operate more effectively.

Practicing CHT within the existing holding capacity will not result in any space and weight impacts. As discussed in the above analyses, there may be situations where practicing CHT may exceed the vessel's existing holding capacity. This would result in space and weight impacts. Extra tank capacity would be required to accommodate any additional volume of bilgewater collected. Because the space and weight allocations on LSD 41 Class vessels are tightly controlled, there is generally very little available unassigned space to accommodate additional tankage. Therefore, the most likely strategy for increasing bilgewater holding capacity would be to convert other existing tanks to bilgewater holding tanks. However, converting existing tank space to hold bilgewater would likely result in adverse impacts to those systems or services that rely on the tanks that would be converted for holding oily waste.

8.3.1.2 Personnel/Equipment Safety

Practicing CHT within the vessel's existing holding capacity will not pose any safety hazards to the vessel’s crew or equipment.

8.3.1.3 Mission Capabilities

Practicing CHT within the vessel's existing holding capacity will not have an impact on ship’s signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

The ship designers review the ship's requirements (e.g., vessel's range, number of crew, etc.) to determine what tank capacities are needed to allow the ship to fulfill its mission. With the exception of approximately five percent excess capacity as a margin of safety, ship designers do not size a vessel's tank capacity beyond what is anticipated to meet the ship's operational requirements. Practicing CHT in excess to the vessel's existing holding capability would likely require that additional tanks be built or tanks used for other purposes be converted to bilgewater holding tanks. Reducing the capacity of existing tanks such as aviation fuel (JP-5) tanks, potable water tanks, or sewage tanks, will reduce the ship's current capability to support its mission.

The USCG mission often requires their vessels to operate for extended periods of time within 12 nm (e.g., search and rescue missions). The USCG may operate their OWS, as necessary and at the discretion of the Commanding Officer, to prevent bilgewater accumulation in excess of the vessels’ current holding capacity and minimize mission impacts. In instances where an USCG vessel is at risk of exceeding its bilgewater holding capacity (e.g., during extensive operations within 12 nm), requiring USCG vessels to practice CHT without the flexibility of processing bilgewater through the OWS would have a significant mission impact. Specifically, if an USCG vessel were required to practice CHT and was at risk of exceeding its current holding capacity, it would have to return to shore to offload bilgewater thus forcing the vessel to discontinue critical mission-related activities.

8.3.1.4 Personnel Impact

Practicing CHT within the vessel's existing holding capacity will not result in any personnel impacts other than time required to oversee the transfer of bilgewater and oily waste to shore (see analysis below).

Practicing CHT as a primary control option does not require additional special training. Manning is required to oversee the transfer of bilgewater to a shore facility [i.e., operate the oily waste transfer (OWT) pump and associated valves/hull connections]. This transfer requires three crewmembers per event as described in Section 8.1.1.4. An LSD 41 Class vessel generates 475,000 gallons of bilgewater annually within 12 nm. The annual volume of bilgewater generated within 12 nm of shore divided by the OWT pump rate of 50 gpm, times three people required for oversight, equals the personnel hours required per year for CHT on LSD 41 Class vessels.

$$\frac{475{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 480 \text{ hrs labor/yr}$$

Table 8-15 provides the annual labor hours required for CHT on an LSD 41 Class vessel.

Table 8-15. CHT Annual Labor Hours (LSD 41 Class)

	MPCD Option: CHT
Operator Hours Within 12 nm	480
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	480

8.3.1.5 Consumables, Repair Parts, and Tools

There are no requirements for consumables, repair parts, or tools associated with CHT.

8.3.1.6 Interface Requirements

Practicing CHT does not require any unique interface requirements. OWT pumps and associated valves, piping, and hull connections exist on this vessel class to support the current practice of shoreside disposal.

8.3.1.7 Control System Requirements

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers).

8.3.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option group.

8.3.2 Cost Analysis – Existing Vessels

The following cost data and calculations are provided to allow the reader to compare costs associated with practicing CHT on an LSD 41 Class vessel. CHT is generally not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12 nm only. Vessels in this class will continue to comply with appropriate regulations beyond 12 nm.

8.3.2.1 Initial Cost

As described Section 8.3.1.3, the reallocation of tank space to increase bilgewater holding capacity on an LSD 41 Class vessel would result in adverse impacts on mission capabilities and personnel. For the cost analysis, it was assumed that bilgewater holding capacity will not be modified. Therefore, the initial cost of acquisition and installation of additional equipment such as tankage and piping systems is assumed to be zero.

8.3.2.2 Recurring Cost

Practicing CHT requires 480 personnel hours per year as explained under Section 8.3.1.4. The annual labor hours multiplied by the $22.64 per hour MPCD operator labor rate produces an annual recurring labor cost of $11,000.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{480 \text{ hrs labor}}{\text{yr}} = \$11{,}000/\text{yr}$$

The annual bilgewater generation rate within 12 nm is 475,000 gallons. Multiplying the volume of bilgewater generated annually within 12 nm by the oily waste disposal unit cost for Navy vessels produces an annual recurring disposal cost of $35,580.

$$\frac{475{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.0749}{\text{gal}} = \$35{,}580/\text{yr}$$

There are a number of U.S. Coast Guard vessels within this vessel group. For comparative purposes, an oily waste disposal cost will be calculated for the Coast Guard based on the oily waste disposal unit cost rates ($0.91 per gallon) for Coast Guard vessels. Multiplying the volume of bilgewater generated annually within 12 nm by the oily waste disposal unit cost for Coast Guard vessels produces an annual recurring disposal cost of $432,300.

$$\frac{475{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$432{,}300/\text{yr}$$

Table 8-16 provides the annual recurring costs of using CHT on an LSD 41 Class vessel.

Table 8-16. Annual Recurring Costs for CHT (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	46
Beyond 12 nm	Navy	-
Within 12 nm	Coast Guard	443
Beyond 12 nm	Coast Guard	-

8.3.2.3 Total Ownership Cost (TOC)

Table 8-17 provides the TOC and annualized cost of practicing CHT on an LSD 41 Class vessel.

Table 8-17. TOC for CHT (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	0	0	0	0
Total Recurring	520	520	4940	4940
TOC (15-yr lifecycle)	520	520	4940	4940
Annualized	44	44	420	420

8.3.3 Practicability and Operational Impact Analysis – New Design Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of practicing CHT on new design vessels.

8.3.3.1 Space and Weight

Ports with wastewater offloading services: As discussed in Section 8.3.1.1, practicing CHT while tied up pierside or transiting to or from a port where shore offloading facilities are available (assuming a total maximum transit time of six hours) will have no space or weight impacts.

Ports without wastewater offloading services: As discussed in Section 8.3.1.1, the current holding capacity of the OWHT (6,500 gallons) is not sufficient to hold all bilgewater generated during an extended port visit (typically two to five days) at a port where shore offloading facilities are not available. Based on typical operating scenarios and bilgewater generation rates, NSWCCD Code 20 determined that a tank (or series of tanks) with a capacity of approximately 17,000 gallons would be required to hold all bilgewater generated during an extended port visit. This is approximately three times larger than the existing OWHT capacity and is a 1.0 percent increase in total dead weight. To support this additional tank volume, the size of the ship must be increased. Increasing the ship's size to support this additional dead weight will require approximately 50 long tons (LT) of additional structure, resulting in a total weight increase of approximately 100 LT and approximately 3 ft in overall ship length. This increase represents a 1.0 percent increase in full load weight over a current LSD 41 Class vessel. Code 20 concluded that increasing the capacity of the CHT system might not accommodate all the wastewater that might be generated during extended operations, and therefore does not recommend enlarging the CHT system (Navy, 2003c).

8.3.3.2 Personnel/Equipment Safety

Practicing CHT within the vessel's holding capacity on new design vessels will not pose any safety hazards to vessel equipment or crew.

8.3.3.3 Mission Capabilities

Practicing CHT within the vessel's existing holding capacity will not impact the mission-related operational capability of LSD Class vessels (Navy, 2003c).

8.3.3.4 Personnel Impact

Practicing CHT would require approximately three crewmembers per event to conduct the transfer of oily wastes to shoreside facilities. Practicing CHT on new design vessels is expected to require 475 total hours of labor per year (Navy, 2003c).

8.3.3.5 Consumables, Repair Parts, and Tools

There are no requirements for consumables, repair parts, or tools associated with practicing CHT on new design vessels.

8.3.3.6 Interface Requirements

Practicing CHT on new design vessels will not have an impact on interface requirements. No additional load would be placed on the ship's electrical plant (Navy, 2003c).

8.3.3.7 Control System Requirements

There are no automated control system requirements associated with CHT. However, crewmembers are required by OPNAVINST 5090.1 (series) to watch for oily wastewater spills (e.g., during shoreside transfers).

8.3.3.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to practicing CHT on new design vessels.

8.3.4 Cost Analysis – New Design Vessels

The following cost data and calculations are provided to allow the reader to compare relative costs associated with practicing CHT on a new design vessel in this vessel group. CHT is generally not practiced beyond 12 nm from shore; therefore, CHT costs are calculated for operation within 12 nm only. Vessels in this class must continue to comply with appropriate regulations when operating beyond 12 nm.

NSWCCD Code 20 estimated the total initial, total recurring, total ownership costs (TOC), and annualized costs for practicing CHT on new design vessels in this vessel group. Those costs are summarized in Table 8-18 below.

8.3.4.1 Initial Cost

The required increase in OWHT volume (17,000 gallons vs. 6,500 gallons) would require new design vessels in this vessel group to add 50 LT of additional steel, adding approximately $750,000 to the initial acquisition cost of each ship (Navy, 2003c).

8.3.4.2 Recurring Cost

Practicing CHT requires 475 total labor hours per year for operation, as explained in Section 8.3.1.4. The labor and disposal costs associated with bilgewater disposal are estimated to be $46,000 annually for the Navy (Navy, 2003c).

The labor and disposal costs associated with bilgewater disposal are estimated to be $443,000 annually for the Coast Guard.

8.3.4.3 Total Ownership Cost (TOC)

Table 8-18 summarizes the TOC and annualized cost of practicing CHT on an LSD 41 Class vessel.

Table 8-18. TOC for CHT System on New Design Vessels (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	750	750	750	750
Total Recurring	516	516	4.90	4.90
TOC (15-yr lifecycle)	1.30	1.30	5.7	5.7
Annualized	107	107	483	483

8.4 EVAPORATION

Commercial evaporation units are designed to operate with freshwater waste streams (Navy and EPA, 2000b). To apply evaporation technology in a saltwater environment, design concerns such as corrosivity, plating-out of salt in the unit, and buildup of sludge would need to be addressed before this technology could be considered feasible on this vessel class. The following analysis is provided to further describe the infeasibility of this MPCD.

As discussed in Section 8.0, LSD 41 Class vessels are equipped with two 10-gpm gravity coalescence OWSs with a combined processing rate of 20 gpm. This OWS operates in batch mode (i.e., operates at maximum capability to eliminate accumulating bilgewater) to minimize the impact on the vessel’s crew A bilgewater evaporator with the maximum available processing rate, one gallon per minute, was chosen for this analysis to minimize the number of units required. A total of 20 evaporation units, each requiring 162 kW of electrical power to operate, would be required to meet the current processing rate. LSD 41 Class vessels have a total electrical capacity of 5,200 kW and a designed operating capacity of 3,510 kW. The designed operating capacity is based on the assumption that one ship service generator is out of service and the remaining generators are operating at 90 percent capacity (Navy, 1980). The designed operating capacity includes a 20 percent service life margin (585 kW) to support the addition of electrical equipment throughout the vessel's lifecycle (Navy, 1980). The service life margin represents the total electrical capacity available to support additional electrical equipment that may be installed following initial construction. The use of evaporators would constitute a total electrical load, 3240 kW, which is greater than the 585 kW service life margin available.

A significant amount of electrical power is required by Armed Forces vessels to support mission-related payloads such as the combat systems (e.g., weapons, command, communications, control, electronic warfare and countermeasures, etc.) and combat support and supply systems. Because the use of evaporators would exceed the vessel's service life margin, mission essential electrical equipment would have to be shut off while running the evaporators. This equipment is essential for vessel safety and defense. Not operating this equipment while running the evaporators would leave the vessel vulnerable to safety hazards (e.g., collisions) and potential military threats. Furthermore, despite the flexibility afforded by new design vessels (e.g., reduced cost of forward-fit installation), new design vessels are not expected to be able to support the evaporators' substantial power requirements. Therefore, based on the evaporators' power requirements that subsequently degrade the vessel's mission and safety capabilities, evaporation is not a feasible MPCD option group for either existing or new design vessels represented by the LSD 41 Class. In addition, design concerns such as corrosivity, plating out of salt in the unit, and buildup of salt and sludge still need to be addressed before this technology may be feasible on this vessel class.

8.5 HYDROCYCLONES

The following sections discuss the feasibility and cost impacts of installing and operating a hydrocyclone on-board an LSD 41 Class vessel.

8.5.1 Practicability and Operational Impact Analysis

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of hydrocyclones.

8.5.1.1 Space and Weight

LSD 41 Class vessels are equipped with two 10-gpm gravity coalescing type OWSs. A single 20-gpm hydrocyclone module (Krebs model Spinifex 4500) is being proposed in this analysis. This unit was chosen because it has a processing capacity similar to the current OWSs in place on LSD 41 Class vessels and is representative in space, weight, and power requirements of hydrocyclones with similar processing capacities. Table 8-19 provides the space and weight of a Krebs Spinifex 4500 Module (20 gpm) consisting of a strainer basket, air operated diaphragm pump, and interconnecting piping.

Table 8-19. Hydrocyclone Specifications (LSD 41 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	20 gpm	2.5 x 1.3 x 5.25	3 x 2 x 7	17	132/150
Total (To achieve required processing capacity)	1	20 gpm	2.5 x 1.3 x 5.25	3 x 2 x 7	17	132/150

The hydrocyclone modules are designed for single-deck operation and would be installed in the current OWS room.   The existing OWS would be removed and replaced with the new hydrocyclone module.

8.5.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with hydrocyclones. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While hydrocyclones require pressurized air to operate, observing standard shipboard safety procedures for handling compressed air systems should be adequate.

8.5.1.3 Mission Capabilities

The installation and operation of a hydrocyclone on LSD 41 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

8.5.1.4 Personnel Impact

There are no impacts on habitability. Hydrocyclones are closed systems, so no vapors are present. Although operation can be fully automated, periodic monitoring of the inlet and underflow pressures is recommended to evaluate operating conditions and determine if maintenance of certain components may be needed.

The hydrocyclone unit runs in automatic mode, but requires general supervision while the unit is operating. Based on an MPCD rated capacity of 20 gpm and the approximate 475,000 gallons of bilgewater generated annually within 12 nm, the hydrocyclone would be operated 400 hours annually within 12 nm.

$$\frac{475{,}000\ \text{gal}}{\text{yr}} \bullet \frac{\text{min}}{20\ \text{gal}} \bullet \frac{\text{hr}}{60\ \text{min}} = 400\ \text{hrs/yr}$$

The labor requirement for general oversight of the hydrocyclone was estimated to be 0.25 hours of general oversight for every two hours of operation. The supervisory labor requirement of 15 minutes for every two hours of operation is based on the assumption that although the unit is automatic, a crewmember will be assigned to general oversight of multiple pieces of equipment at once. Therefore, the annual labor requirement associated with the operation of a hydrocyclone within 12 nm is 49 hours.

$$\frac{400\ \text{hrs operation}}{\text{yr}} \bullet \frac{0.25\ \text{hr labor}}{2\ \text{hrs operation}} = 49\ \text{hrs labor/yr}$$

In addition, the waste oil removed from the bilgewater must be transferred to a shore facility. This transfer requires three crewmembers per event as described under Section 8.1.1.4. The labor hours associated with transferring the waste oil produced within 12 nm of shore is calculated by dividing the waste oil volume (1 percent of the annual bilgewater volume generated while operating within 12 nm) by the waste oil pump rate (50 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}750 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 4.8 \text{ hrs labor/yr}$$

The combined annual labor associated with the operational oversight of a hydrocyclone unit within 12 nm and transfer of waste oil generated within 12 nm on an LSD 41 class vessel is 54 hours.

The total labor requirement associated with vessel operations beyond 12 nm includes MPCD operator oversight (i.e., 15 minutes for every two hours of equipment operation) and labor required to oversee the offloading of waste oil to shore attributable to vessel operation beyond 12 nm. The annual labor requirement associated with operating this MPCD beyond 12 nm is calculated using the same methodology used to calculate the annual labor requirement within 12 nm. Hours of MPCD operation and annual labor requirements are presented below.

Hours of MPCD operation beyond 12 nm:

$$\frac{1{,}900{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{20 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 1{,}600 \text{ hrs labor/yr}$$

Labor requirement for MPCD operator oversight:

$$\frac{1{,}600 \text{ hrs}}{\text{yr}} \bullet \frac{0.25 \text{ hrs labor}}{2 \text{ hrs}} = 198 \text{ hrs labor/yr}$$

Labor requirement for offloading waste oil:

$$\frac{19{,}000 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 19 \text{ hrs labor/yr}$$

Total MPCD operator labor and waste oil offloading oversight associated with the operation of a hydrocyclone on an LSD 41 Class vessel class beyond 12 nm is 217 hrs/yr.

Annually, the hydrocyclone requires approximately 1.5 personnel hours of time-based maintenance, 0 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Table 8-20 and Table 8-21 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for the hydrocyclone.

Table 8-20. Hydrocyclone Time-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and Inspect Strainer	0.25	3 months	1
Inspect Air Diaphragm Pump for Wear	0.25	12 months	0.25
Replace Diaphragm in Pump	0.25	12 months	0.25
Total Annualized Hours (per unit)	-	-	1.5
Total Annualized Hours (total)	-	-	1.5

Table 8-21. Hydrocyclone Condition-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 400 operation hours within 12 nm)	Annualized Maintenance Hours (based on 1600 operation hours beyond 12 nm)
-	0	0	0	0
Total Annualized Hours (per unit)	-	-	-	0
Total Annualized Hours (total)	-	-	-	0

Table 8-22 provides the annual labor hours required to operate and maintain the hydrocyclone unit.

Table 8-22. Hydrocyclone Annual Labor Hours (LSD 41 Class)

	MPCD Option: Hydrocyclone (hours/unit)
Operator Hours Within 12 nm	54
Operator Hours Beyond 12 nm	217
Condition-based Maintenance Within 12 nm	0
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	1.5
Total Time	273

Hydrocyclones do not have an impact on habitability. Hydrocyclones are closed systems, so no vapors are present. Manning requirements will be minimal because the hydrocyclones require little maintenance, and operation can be fully automated. Periodic monitoring of the inlet and underflow pressures would be recommended to evaluate operating conditions and determine if maintenance is needed.

8.5.1.5 Consumables, Repair Parts, and Tools

Consumables and repair parts, which should be on hand, include "O" rings and gaskets for the cyclone, a few spare cyclone liners, and some components (e.g., replacement diaphragm) for the pump.

8.5.1.6 Interface Requirements

Table 8-23 summarizes the specific system interface requirements associated with the hydrocyclones.

Table 8-23. Hydrocyclone Interface Requirements (LSD 41 Class)

Shipboard System	20-gpm unit
Compressed Air	65 psi, 27 sfcm

LSD 41 Class vessels are able to accommodate this interface requirement.

8.5.1.7 Control System Requirements

Hydrocyclones are generally designed to operate in either automatic or manual mode. Automatic operation is the normal operating mode. When placed in the automatic mode, activation of the units is controlled by tank level switches, which are installed in the OWHT. One level switch starts the unit when the liquid level in the tank reaches a pre-set level. When the liquid level in the OWHT drops to a pre-set level, a second level switch signals the unit(s) to shut down. Units have a flow sensor that will secure the system if the pump loses suction, and a remote alarm/indicator panel that allows shipboard personnel to monitor the operating status of the units while in the automatic mode of operation.

8.5.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

8.5.2 Cost Analysis

The following cost data and calculations are provided to allow the reader to compare relative costs associated with a hydrocyclone system on an LSD 41 Class vessel.

8.5.2.1 Initial Cost

The hydrocyclone system procurement cost is $7,600 per vessel (Lima, 2000). Based on an LSD 47 (an LSD 41 Class vessel) ship check, the installation of the 20-gpm hydrocyclone will cost $100,300 per vessel (Navy, 2000). To install the unit, the existing gravity coalescence unit must first be removed from the OWS room in order to make space available for the hydrocyclone system. The installation would require approximately five weeks to complete. Technical manuals cost approximately $85,000 ($10,630 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $25,120 ($3,140 per vessel) (Navy, 2000). The cost for training materials is approximately

$9,330 ($1,166 per vessel) (Smith, 2001). The initial cost of a hydrocyclone system on an LSD 41 Class vessel is $122,800.

8.5.2.2 Recurring Cost

Personnel Labor Within 12 nm

This MPCD requires 56 personnel hours per year for operation and time-based maintenance within 12 nm, as explained under Section 8.5.1.4. The number of annual labor hours multiplied by the $22.64 hourly MPCD operator labor rate produces the first operating year recurring labor cost within 12 nm.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{56\text{ hrs labor}}{\text{yr}} = \$1{,}300/\text{yr}$$

Personnel Labor Beyond 12 nm

This MPCD requires 217 personnel hours per year for operation beyond 12 nm, as explained under Section 8.5.1.4. The annual labor cost associated with operating this MPCD beyond 12 nm is calculated using the same hourly labor rate used to calculate the annual labor cost within 12 nm, as shown below.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{217\text{ hrs labor}}{\text{yr}} = \$4{,}910/\text{yr}$$

The labor required to transfer waste oil generated by the hydrocyclone system to a disposal activity is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal activity is assumed to dispose of the waste oil at no charge for Navy vessels.

Coast Guard vessels pay $0.91 per gallon to dispose of their waste oil (Volpe, 2000a). The recurring cost incurred by the Coast Guard to dispose of the waste oil generated within 12 nm is shown below.

$$\frac{4{,}750\,\text{gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$4{,}323/\text{yr}$$

The recurring cost incurred by the Coast Guard to dispose of waste oil generated beyond 12 nm is shown below.

$$\frac{19{,}000\,\text{gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$17{,}290/\text{yr}$$

Table 8-24 summarizes the annual recurring costs for a gravity coalescer system used on an LSD 41 Class Vessel.

Table 8-24. Annual Recurring Costs for Hydrocyclone (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	1.3
Beyond 12 nm	Navy	4.91
Within 12 nm	Coast Guard	5.6
Beyond 12 nm	Coast Guard	22.2

8.5.2.3 Total Ownership Cost (TOC)

Table 8-25 summarizes the TOC and annualized cost for a 15-year lifecycle for a hydrocyclone system on an LSD 41 Class vessel.

Table 8-25. TOC for Hydrocyclone (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	123	123	123	123
Total Recurring	14.5	69.0	62.4	310
TOC (15-yr lifecycle)	138	192	185	433
Annualized	11.7	16.3	15.8	36.8

8.6 *IN SITU* BIOLOGICAL TREATMENT

In situ biological treatment of bilgewater is the addition of microbes to a vessel's bilge spaces to digest the oil content of the bilgewater. For *in situ* biological treatment to be effective, the microbes must be left in the bilge for a sufficient period of time to digest the bilgewater's oil content. According to the vendor, the most effective use of *in situ* biological treatment for the wastewater that accumulates in the bilge is to leave the *in situ* material in the bilge spaces on the vessel for a 30-day period to establish a population of microbes (Opsanick, 2000). Transferring bilgewater to shore or allowing additional bilgewater to be introduced to the bilge spaces before the 30-day period is complete may decrease the *in situ* biological treatment's effectiveness. Due to the lack of performance data, the extent to which the effectiveness of biological treatment would be decreased cannot be determined (Opsanick, 2000). However, the vessel would be continuously generating bilgewater during this period, disrupting the batch processing method recommended by the manufacturer. Further, the vessel’s total bilgewater generation over a 30-day period is at least 750,000 gallons. Leaving this volume of bilgewater in the bilge spaces to allow more complete treatment would inhibit the safe operation of existing or new design vessels. Therefore, *in situ* biological treatment is not a feasible MPCD option group for existing or new design vessels represented by LSD 41 Class vessels.

8.7 OIL ABSORBING SOCKS (OASS)

OASs are designed to absorb oil floating on the surface of a body of water (Sorbent Products Inc., 2000). In this application, OASs would be placed inside the bilge areas of an LSD 41 Class vessel to continuously absorb the waste oil from the bilgewater. When the OASs become fully saturated they are manually removed and replaced with new OASs. This use of OASs for LSD 41 Class vessels pose concerns regarding the generation of solid waste, a potential to restrict emergency dewatering, and a potential fuel source that could contribute to the intensity of an engine room fire.

The use of OASs for LSD 41 Class vessels will result in the generation of a large amount of solid waste. As noted earlier, LSD 41 Class vessels generate approximately 25 gallons of waste oil per day while in port and 100 gallons per day while underway. The density of a saturated OAS is approximately 7.3 pounds per gallon of waste oil (Ergon Environmental Products Inc., 1998). OASs are solid media that trap and hold waste oil, a liquid. Therefore, using OASs would generate approximately 183 pounds of solid waste per day while in port. If used underway, OASs would generate approximately 730 pounds of solid waste per day. The removal of saturated OASs would require a high level of manual effort (i.e., labor provided by the ship's crew). The saturated OASs would need to be removed from the bilge and carried up from the lower decks of the vessel so they could be transferred to shore. By comparison, waste oil captured by the current MPCD option (i.e., the gravity coalescing OWS) remains a liquid waste stream and would only require a few minutes to pump the same amount ashore.

The presence of OASs in the bilge spaces would potentially restrict the flow of bilgewater through normal and emergency dewatering pumps and strainers by clogging the suction points. The use of OASs in the bilge spaces of Navy vessels would not be feasible due to vessel safety and survivability concerns. The Navy prohibits (through practice) the presence of any loose materials or debris in the bilge areas that could potentially interfere with normal or emergency dewatering activities. Securing the OASs to a pipe or other type of fixture in the bilge is not feasible because the force of a shock or explosion would potentially dislodge the OAS. Furthermore, as the OAS absorbs oil it becomes a concentrated fuel source for a fire that could contribute to the intensity of an engine room fire.

Based on the potential operational and safety impacts related to solid waste handling, emergency dewatering, and potential fire hazards, OASs are not a feasible MPCD option group for the LSD 41 Class vessel group. New design vessels cannot resolve these impacts.

8.8 FILTER MEDIA

The following sections discuss the feasibility and cost impacts of installing and operating a filter media secondary OWS system on-board an LSD 41 Class vessel. Although primary OWSs installed on-board LSD 41 Class vessels generally have a combined rated capacity of 20 gpm, due to space constraints, the Navy is considering the installation of one 10-gpm filter unit on-board LSD 41 Class vessels. The Navy expects one unit to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is more critical. Once beyond 12 nm, the vessel will operate its primary OWS and continue to operate in compliance with regulatory requirements.

8.8.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of filter media systems.

8.8.1.1 Space and Weight

One 10-gpm filter media polisher is proposed for this analysis. The polishing unit consists of oil absorbing filter media canisters and is designed to treat the OWS effluent before being discharged overboard. The 10-gpm filter media polisher was selected as the secondary MPCD due to its ability to match the capacity requirements of the current MPCD and because the unit has been tested on some Navy vessels (e.g., DDG 51 Class). The polishing unit is comprised of three cylindrical tanks, installed in a triangular pattern, with each tank containing three canisters filled with an oil absorbing media. The OWS filter media polisher is intended for single-deck operation and would be installed in Auxiliary Machinery Room No. 2 at frame 58. Relocation of an existing workbench and phone would be required to provide an installation envelope (Navy, 2000). Table 8-26 summarizes the approximate space and weight of a 10-gpm unit.

Table 8-26. OWS Filter Media Polisher Specifications (LSD 41 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	4 x 1.3 x 3.25	5.6 x 2.8 x 5.25	16.9	730/1675
Total (To achieve required processing capacity)	1	10 gpm	-	-	16.9	730/1675

8.8.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with this MPCD. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the filter media.

8.8.1.3 Mission Capabilities

The installation and operation of this MPCD on LSD 41 Class vessels are not expected to have an impact on ship's signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

8.8.1.4 Personnel Impact

Filter media polisher systems run in automatic mode, but require basic oversight while the unit is operating. The number of hours the polisher system is operated annually within 12 nm is 780 hours.

$$\frac{470{,}300\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} = 780\text{ hrs/yr}$$

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary unit will not require significant additional oversight. Therefore, operator oversight hours associated with the secondary unit are assumed to be zero. The recovered waste oil is absorbed into filter media canisters that must be offloaded. The time required to replace the filter media canisters is one hour for each unit. Because LSD 41 Class vessels would be equipped with one unit, the total time required to replace the filter media canisters is one hour. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total rated capacity of 10 gpm and a total of 470,300 gallons (equal to bilgewater generated annually within 12 nm minus 1 percent of oil removed by primary OWS) of effluent to be processed annually, the filter media will have to operate approximately 780 hours per year. Therefore, the filter media canister will have to be replaced every 6 months. The annual number of hours spent replacing the filter media canisters is 2 hours per year.

$$\frac{470{,}300\text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10\text{ gal}} \bullet \frac{\text{hr}}{60\text{ min}} \bullet \frac{1\text{ hr labor}}{400\text{ hrs}} = 2\text{ hrs labor/yr}$$

Annually, the filter media canisters require 0 personnel hours of time-based maintenance, 2 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Condition-based maintenance beyond 12 nm is assumed to be equal to zero because secondary MPCDs are only operated with 12 nm. Table 8-27 and Table 8-28 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for one filter media polisher.

Table 8-27. Filter Media Time-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
None	0	0	0
Total Annualized Hours (per unit)	-	-	0
Total Annualized Hours (total)	-	-	0

Table 8-28. Filter Media Condition-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 784 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Replace Filter Media Canisters	1	400	2	-
Total Annualized Hours (per unit)	-	-	2	-

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 784 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Total Annualized Hours (total)	-	-	2	-

Table 8-29 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

Table 8-29. Filter Media Annual Labor Hours (LSD 41 Class)

	MPCD Option: Filter Media (hours/unit)
Operator Hours Within 12 nm	0
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	2
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	0
Total Time	2

8.8.1.5 Consumables, Repair Parts, and Tools

The OWS filter media polishing unit requires the replacement of nine filter media canisters (3 canisters per tank) every six months (see Section 8.8.1.4). The canisters may be stored on the vessel or shoreside. No special repair parts or tools are required for the operation or maintenance of these units.

8.8.1.6 Interface Requirements

No specific system interface requirements are associated with the OWS filter media polishing unit.

8.8.1.7 Control System Requirements

The OWS filter media polishing unit operates automatically in response to the primary OWS operation. Therefore, the polisher unit does not have any unique control system requirements.

8.8.1.8 Other/Unique Characteristics

The filter media polishing unit discussed above was installed on two DDG 51 Class vessels for test and evaluation. The units were removed from both ships because they failed to consistently produce an effluent with an oil content less than 15 parts per million (Price, 1999). Navy ships with OWSs and Oil Content Monitors should attempt to limit oil and oily discharges to 15 ppm oil worldwide (Navy, 2002).

8.8.2 Cost Analysis – Existing Vessels

The following cost data and calculations are provided to allow the reader to compare costs associated with a filter media unit on an LSD 41 Class vessel.

8.8.2.1 Initial Cost

The filter media polisher procurement cost is $15,680 per vessel (Hanrahan, 1997). Based on ship drawing analysis and an LSD 47 (an LSD 41 Class vessel) ship check, the Navy estimates that the installation will cost $108,600 per vessel (Navy, 2000). The unit would be installed in Auxiliary Machinery Room No. 2, at frame 58, and would require the relocation of an existing workbench and phone to provide adequate room for installation (Navy, 2000). The installation would require approximately four weeks to complete. Technical manuals cost approximately $85,000 ($10,630 per vessel) to develop a 150-page manual (Gallagher, 1999). The Navy estimates that the development of technical drawings will cost $14,000 ($1,690 per vessel) (Navy, 2000). The cost for training materials is approximately $9,330 ($1,166 per vessel) (Smith, 2001). The total initial cost of the filter media polishing system on an LSD 41 Class vessel is $145,000 per vessel.

8.8.2.2 Recurring Cost

The filter media requires 2 personnel hours per year for operation and maintenance, as explained under Section 8.8.1.4. The annual labor hours multiplied by the $22.64 per hour MPCD operator labor rate produces the labor cost of $44/year.

$$\frac{\text{2 hrs labor}}{\text{yr}} \bullet \frac{\$22.64}{\text{hr labor}} = \$44/\text{yr (within 12 nm)}$$

The replacement cost of filter media canisters is $7,300 per unit (Hanrahan, 1997). Because this vessel class requires one unit, the cost for canister consumables at each replacement interval is $7300. The filter media canisters must be replaced after approximately 400 hours of operation (Galecki, 2000). With a total rated capacity of 10 gpm and a total of 470,300 gallons of effluent to be processed annually, the filter media will have to operate approximately 780 hours per year. Therefore, the filter media will have to be replaced approximately every 6 months, which results in an annual cost of $14,000.

$$\frac{\text{470,300 gal}}{\text{yr}} \bullet \frac{\text{min}}{\text{10 gal}} \bullet \frac{\text{hr}}{\text{60 min}} \bullet \frac{\text{1 replacement}}{\text{400 hrs}} \bullet \frac{\$7,300}{\text{replacement}} = \$14,000/\text{yr}$$

The filter media canisters are combined and disposed of with the vessels' solid waste. Because of the relative infrequency and small volumes disposed, the Navy does not expect any significant increase in their overall solid waste disposal cost.

The filter media canisters absorb the oil content of the oily bilgewater. Because media canisters absorb the oil content, the filter media system does not produce any additional waste oil that must be offloaded from the vessel via the waste oil tank. Table 8-30 summarizes the annual recurring costs for a filter media system used on an LSD 41 Class vessel.

Table 8-30. Annual Recurring Costs for Filter Media (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	14
Beyond 12 nm	Navy	-
Within 12 nm	Coast Guard	14
Beyond 12 nm	Coast Guard	-

8.8.2.3 Total Ownership Cost (TOC)

Table 8-31 summarizes the TOC and annualized cost over a 15-year lifecycle for a filter media system on an LSD 41 Class vessel.

Table 8-31. TOC for Filter Media (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	145	145	145	145
Total Recurring	160	160	160	160
TOC (15-yr lifecycle)	301	301	301	301
Annualized	25.6	25.6	25.6	25.6

8.8.3 Practicability and Operational Impact Analysis – New Design Vessels

The practicability and operational impact of using filter media systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by LSD 41 Class vessels.

8.8.4 Cost Analysis – New Design Vessels

The installation cost would be different for new design vessels, however all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 8.8.1 and 8.8.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the filter media installation cost estimate for existing vessels within this group. Using this factor, the assumed installation costs for the new design LSD 41 vessel group is $72,750, per vessel. The projected total initial cost for a filter media system aboard these new design vessels is $102,000, per vessel. Table 8-32 summarizes the costs for these new design vessels.

Table 8-32. TOC for Filter Media on New Design Vessels (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	102	102	102	102
Total Recurring	160	160	160	160
TOC (15-yr lifecycle)	262	262	262	262
Annualized	21.9	21.9	21.9	21.9

8.9 MEMBRANE FILTRATION

The following sections discuss the feasibility and cost impacts of installing and operating a membrane filtration [ultrafiltration (UF)] secondary OWS unit on-board an LSD 41 Class vessel. The polishing unit consists of UF membranes and is designed to treat OWS effluent before being discharged overboard. Although primary OWSs installed on-board LSD 41 Class vessels generally have a combined rated capacity of approximately 20 gpm, due to space constraints, the Navy is planning to install one 10-gpm membrane filtration unit on-board LSD 41 Class vessels. The Navy expects one unit to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is more critical. Once beyond 12 nm, the vessel will operate its primary OWS and continue to operate in compliance with regulatory requirements.

8.9.1 Practicability and Operational Impact Analysis – Existing Vessels

This section analyzes specific feasibility criteria relative to the physical characteristics and operational requirements of membrane filtration.

8.9.1.1 Space and Weight

The 10-gpm UF membrane was selected as the secondary MPCD due to its ability to match capacity requirements of the current primary OWS and because the unit was developed specifically for Navy vessels. The Navy expects this capacity to be sufficient for processing the amount of bilgewater generated within 12 nm where an effluent with low oil concentration is most critical. Once beyond 12 nm, the vessel will operate its primary OWS only and continue to operate in compliance with regulatory requirements. Table 8-33 summarizes the space and weight of a 10-gpm unit.

Table 8-33. Membrane Filtration Specifications (LSD 41 Class)

Physical Properties	Number of Units	Capacity	Size (ft.) L x W x H	Maintenance Envelope (ft.)	Volume (ft^3)	Weight (lbs.) Dry/Flooded
Per unit	1	10 gpm	7 x 5 x 6.5	7 x 5 x 6.5	227.5	2700/3000
Total (To achieve required processing capacity)	1	10 gpm	-	-	227.5	2700/3000

Installing one 10-gpm membrane system on LSD 41 Class vessels would result in space and weight impacts. However, based upon knowledge gained through the prototype installations on-board some DDG 51 and LSD 41 Class vessels, these impacts are not considered prohibitive.

UF units are designed to treat the effluent from primary treatment devices (such as a gravity coalescer) and are therefore installed in close proximity to the OWS, in Auxiliary Machine Room No. 2 at frame 58. An existing workbench and phone will have to be relocated. Similar impacts can be expected for other vessels in the vessel group represented by this vessel.

Experience with prototype units installed on some DDG 51 and LSD 41 Class vessels indicates that care must be taken to properly locate the membrane system to avoid any adverse traffic impacts. UF membrane units are designed for single-deck operation. They can be provided to the installing activity fully assembled, or designed for easy disassembly into components small enough to fit through standard watertight doors. UF membranes systems will require minimal storage of additional spare parts (Price, 1999).

8.9.1.2 Personnel/Equipment Safety

There are no unusual personnel or equipment safety hazards associated with membrane systems. Other than wearing standard personal protective equipment (e.g., rubber gloves/boots and safety glasses/goggles) during maintenance activities, no special devices or precautions are necessary. Any hazardous materials (e.g., oil and grease) required for operation and maintenance are minimal in quantity and authorized for use. Standard afloat control and management procedures are adequate for use and disposal of the material. While membrane systems require electrical power and operate under high pressures, observing standard shipboard safety procedures for handling electrical equipment and pressurized systems should be adequate. A Failure Mode, Effects, and Criticality Analysis (FMECA) was generated for the UF system used on the USS CARNEY (DDG 64). The FMECA lists potential system failures according to their relative probability of occurrence, identifies safety hazards resulting from those failures, and recommends safety practices to reduce the associated safety risk. Applicable safety practices recommended by the FMECA will likely be implemented in conjunction with UF system installation on-board the LSD 41.

8.9.1.3 Mission Capabilities

The installation and operation of membranes on LSD 41 Class vessels are not expected to have an impact on ship’s signature, war fighting capabilities, mobility, or on any mission critical systems or operations.

8.9.1.4 Personnel Impact

UF systems run in automatic mode, but require basic oversight while the unit is operating. The number of hours the UF system is operated annually is 780 hours.

$$\frac{470{,}300 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{10 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} = 780 \text{ hrs/yr}$$

It is assumed that because a secondary OWS unit runs in conjunction with a primary OWS unit, the secondary unit will not require significant additional oversight. Therefore, operator oversight hours associated with the secondary unit are assumed to be zero.

The waste oil removed from the bilgewater by the UF system must be transferred to a shore facility. This transfer requires three crewmembers per event as described under the Section 8.1.1.4. The labor hours associated with oversight of transfer of waste oil produced by a UF system on an LSD 41 Class vessel are calculated by dividing the waste oil volume (1 percent of the UF effluent volume) by the waste oil pump rate (50 gpm) and multiplying by the number (three) of crewmembers.

$$\frac{4{,}703 \text{ gal}}{\text{yr}} \bullet \frac{\text{min}}{50 \text{ gal}} \bullet \frac{\text{hr}}{60 \text{ min}} \bullet \frac{3 \text{ hrs labor}}{\text{hr}} = 4.7 \text{ hrs labor/yr}$$

Annually, membrane filtration requires approximately 9.3 personnel hours of time-based maintenance, 4.4 personnel hours of condition-based maintenance within 12 nm, and 0 personnel hours of condition-based maintenance beyond 12 nm. Because secondary MPCDs are operated within 12 nm, condition-based maintenance beyond 12 nm is assumed to be zero. Table 8-34 and Table 8-35 summarize the time-based maintenance and the condition-based maintenance requirements, respectively, for the membrane filtration system.

Table 8-34. Membrane Filtration Time-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Clean and inspect permeate flow sensor	0.2	3 months	0.8
Clean and inspect recirculation loop temperature sensor	0.2	3 months	0.8
Clean and inspect continuous level transducer	0.2	6 months	0.4
Clean and inspect high level sensor probe	0.2	6 months	0.4
Calibrate pressure gauges	1.0	12 months	1.0
Clean and inspect recirculation pump suction valve	1.8	12months	1.8
Clean membranes (no MRC; for scheduling only. Perform CLEAN cycle. Perform quarterly and when membrane resistance is greater than 100% as indicated on the control panel)	0.1	3 months	0.4
Clean and inspect membrane system control panel	1.6	6 months	3.2

Maintenance Activity	Maintenance Time (hours)	Frequency	Annualized Maintenance Time (hours)
Inspect membrane system grounding straps	0.1	12 months	0.1
Perform lamp test of membrane system control panel; measure insulation resistance.	0.1	3 months	0.4
Total Annualized Hours (per unit)			9.3
Total Annualized Hours (total)			9.3

Table 8-35. Membrane Filtration Condition-Based Maintenance (LSD 41 Class)

Maintenance Activity	Maintenance Time (hours)	Frequency (based on hours of MPCD operation)	Annualized Maintenance Hours (based on 780 operation hours within 12 nm)	Annualized Maintenance Hours (based on 0 operation hours beyond 12 nm)
Replace membranes (accomplished shoreside)	3	2400	.98	0
Drain membrane system	1	600	1.3	0
Fill membrane system with water	1	500	1.6	0
Replace feed pump mechanical seal. Inspect internal parts	2.5	10000	.20	0
Replace recirculation pump mechanical seal. Inspect internal parts	5	10000	.39	0
Total Annualized Hours (per unit)	-	-	4.4	0
Total Annualized Hours (total)	-	-	4.4	0

Table 8-36 provides the annual labor hours required to operate and maintain the proposed MPCD discussed in this section.

Table 8-36. Membrane Filtration Annual Labor Hours (LSD 41 Class)

	MPCD Option: Membrane Filtration (hours/unit)
Operator Hours Within 12 nm	4.7
Operator Hours Beyond 12 nm	0
Condition-based Maintenance Within 12 nm	4.4
Condition-based Maintenance Beyond 12 nm	0
Time-based Maintenance	9.3
Total Time	18.4

8.9.1.5 Consumables, Repair Parts, and Tools

On vessels equipped with the UF system, membranes are scheduled to be replaced after approximately 2400 hours of use. At this time, a new, clean set of membranes is put in the UF system and the old, used one is sent to shore to be cleaned. This regular maintenance does not require any consumables, as the membranes are exchanged. Furthermore, no special tools are required to operate or maintain the units.

8.9.1.6 Interface Requirements

Table 8-37 summarizes the interface requirements of the UF system. These requirements are not expected to have a substantial impact on LSD 41 Class vessels.

Table 8-37. Membrane Filtration Interface Requirements (LSD 41 Class)

Shipboard System	Interface Requirement (10 gpm system)
Electric Power	440 Volts/3 Phase/ 60Hz/7.5 kW (10 hp)
Compressed Air	80 to 100 psi, 5 scfm (operate valve actuators)
Potable Water	Fresh water back flush of membranes 10 gpm @ 30 psi
Drainage	Concentrate from Recirculation Sub-system drains to WOT. When back flushing membranes, oily waste flushed from system is diverted to OWHT.

8.9.1.7 Control System Requirements

The UF system operates automatically in response to the primary OWS operation. Therefore, the UF system does not have any unique control system requirements.

8.9.1.8 Other/Unique Characteristics

No other/unique characteristics have been identified with respect to this MPCD option.

8.9.2 Cost Analysis – Existing Vessels

The following cost data and calculations are provided to allow the reader to compare costs associated with a UF system on an LSD 41 Class vessel.

8.9.2.1 Initial Cost

The system (i.e., one unit) procurement cost is $200,000 per vessel (Smith, 1999). Based on ship drawing analysis and an LSD 47 (an LSD 41 Class vessel) ship check, the Navy estimates that installation of the unit will cost $112,000 per vessel (Navy, 2000). The UF membrane would be installed in close proximity to the OWS, in Auxiliary Machine Room No. 2 at frame 58, and relocation of an existing workbench and phone would be required to provide room for installation. The installation would require approximately five weeks to complete. Technical manuals cost approximately $85,000 ($10,630 per vessel) to develop a 150-page manual (Gallager, 1999). The Navy estimates that the development of technical drawings will cost $18,350 ($2,294 per vessel) (Navy, 2000). The cost for training materials is approximately

$9,330 ($1,166 per vessel) (Smith, 2001). The total initial cost of a UF system on an LSD 41 Class vessel is $330,000 per vessel.

8.9.2.2 *Recurring Cost*

The UF membrane system requires 18.4 personnel hours per year for operation, condition-based maintenance, and time-based maintenance as explained under Section 8.9.1.4. The annual labor hours multiplied by the $22.64 per hour MPCD operator labor rate produces the first operating year recurring labor cost of $417.

$$\frac{\$22.64}{\text{hr labor}} \bullet \frac{18.4 \text{ hrs labor}}{\text{yr}} = \$417/\text{year (within 12 nm)}$$

The labor required to transfer waste oil generated by the membrane filtration system to a disposal facility is included in the above labor cost estimates. As explained in Section 1.1.2, the disposal facility is assumed to dispose of the waste oil at no charge for Navy vessels. Coast Guard vessels pay a fee to dispose of their waste oil. The annual cost incurred by the Coast Guard to dispose of the waste oil generated within 12nm is shown below.

$$\frac{4{,}703\,\text{gal}}{\text{yr}} \bullet \frac{\$0.91}{\text{gal}} = \$4{,}279\,/\text{yr (per vessel)}$$

Table 8-38 summarizes the annual recurring costs for a UF system used on an LSD 41 Class vessel.

Table 8-38. Annual Recurring Costs for Membrane Filtration System (LSD 41 Class)

Vessel Operating Parameter	Disposal Cost Used	Annual Recurring Cost ($K)
Within 12 nm	Navy	0.417
Beyond 12 nm	Navy	0
Within 12 nm	Coast Guard	4.696
Beyond 12 nm	Coast Guard	0

8.9.2.3 Total Ownership Cost (TOC)

Table 8-39 summarizes the TOC and annualized cost over a 15-year lifecycle for a UF membrane system on an LSD 41 Class vessel.

Table 8-39. TOC for Membrane Filtration System (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	330	330	330	330
Total Recurring	4.65	4.65	52.34	52.34
TOC (15-yr lifecycle)	331	331	380	380
Annualized	28.1	28.1	32.2	32.2

8.9.3 Practicability and Operational Impact Analysis – New Design Vessels

The practicability and operational impact of using UF membrane systems on new design vessels in this vessel group are expected to be similar to the impact on existing vessels in this group, as represented by LSD 41 Class vessels.

8.9.4 Cost Analysis – New Design Vessels

The installation cost would be different for new design vessels; however, all other costs are not expected to change. Therefore, except for the installation cost and the adjusted TOC, this new design analysis refers to Sections 8.9.1 and 8.9.2 for all other feasibility factors. As discussed in Section 1.2, to estimate the new design installation cost, a factor of 67 percent was applied to the UF membrane system cost estimate for the existing vessels within this group. Using this factor, the assumed installation costs for new design LSD 41 vessel group is $75,000, per vessel. The projected total initial cost for an UF membrane system aboard these new design vessels is $289,000, per vessel. Table 8-40 summarizes the costs for these new design vessels.

Table 8-40. TOC for UF Membrane System on New Design Vessels (LSD 41 Class)

Cost ($K)	Other Military Services Vessel Operation Within 12 nm	Other Military Services Vessel Operation Within + Beyond 12 nm	USCG Vessel Operation Within 12 nm	USCG Vessel Operation Within + Beyond 12 nm
Total Initial	289	289	289	289
Total Recurring	4.65	4.65	52.34	52.34
TOC (15-yr lifecycle)	294	294	342	342
Annualized	25.0	25.0	29.0	29.0